VEGETATION CLASSIFICATION

OF AN AREA ON COAL MEASURES

BULLER

NEW ZEALAND

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A thesis submitted
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SUMMARY

The plant communites of a coastal hillslope, Buller, were classified on the basis of floristic presence/absence of 138 species. Six forest communites were identified from 75 descriptions on a forest remnant on tertiary Brunner coal measure parent material and 17 from a comparative area on upper cambrian Greenland greywacke. Community distribution was not affected by differences in underlying parent material. Forest community distribution related to elevational gradients, landform type, slope and aspect. Compositional changes were gradual with the most distinctive separation between steep, low altitude hard beech (*Nothofagus truncata*) dominated communities and low sloping montane to subalpine mountain beech (*Nothofagus solandri* var *cliffortioides*) dominated groups.

This study encompasses an area of much broader elevational and floristic range, under higher rainfall and extremely acidic soils, than previous coal measure vegetation classification studies have documented. Lowland communities in this study differed from those previously identified in the Ngakawau Ecological District. Preservation of this diverse, complex coastal hillslope forest system is recommended.

1. INTRODUCTION

1.1. Introduction

The relationship between forest vegetation community, landform and soil patterns has been examined in a number of lowland and montane studies in south, central and north Westland (e.g Smith & Lee 1984, Stewart & Harrison 1987, Duncan *et al* 1990), with one in west Nelson (Rose 1985). Vegetation patterns have been shown to reflect landform stability, surface age, soil development (Stewart & Harrison 1987), slope and drainage (Norton & Leathwick 1990), parent material, altitude and rainfall gradients (Rose 1985). Few studies have examined steepland forest patterns in Westland (Stewart & Harrison 1987).

There have been virtually no similar studies in the Buller region. A protected natural areas survey identified forest, shrub and open communities in the Ngakawau Ecological District (Kilvington *et al* 1990) but did not study these in depth. Some forested hillslopes described have been modified greatly by burning (Kilvington *et al* 1990); particularly coastal hillslopes underlain by coal measures.

Detailed documentation of forest coal measure communities is limited, apart from Kilvington et al (1990). Rogers (1982) studied a small area in north west Nelson, and Bayfield (1986) described a lowland area in north Taranaki.

Continuing habitat destruction and the urgency to identify and preserve representative examples of natural ecosystems and landforms has become of great concern in New Zealand (Mark 1985, Kelly & Park 1986). The protected natural areas programme developed to counter this problem is a rapid survey method (Myers et al 1987) which identifies areas but does not study ecosystem distribution in depth.

1.2. Objectives

This study examines in detail the only remaining intact area of coastal coal measure hillslope forest in the Ngakawau Ecological District, Buller; at Mount Rochfort forest. The study was undertaken with two objectives in mind: to describe the communities present at Mount Rochfort and examine what governs their distribution, and to identify whether these communities differ significantly from coastal hillslopes on other parent materials and thus should be preserved.

2. METHODS

2.1. Study areas

2.1.1. Main study area: Mount Rochfort forest

Mount Rochfort forest is situated at approximately 41°46'S 171°44'E in the Ngakawau Ecological District, ten kilometres east of Westport, Buller (Fig 2.1).

The area of study, below the summit of Mount Rochfort at the southern end of the Denniston Plateau, rises in elevation from approximately 100 metres a.s.l to 950 metres a.s.l (Fig 2.2). A ridgeline, running downhill either side of the area, marks the southwest and northeast boundaries. A creek runs to parallel to both boundaries. Lake Rochfort, in the centre, divides the area in two. Above the lake the topography is relatively undissected with a series of low sloping backslopes and steppes running perpendicular to the slope (Fig 2.3). Below the lake the topography is much steeper and more dissected forming two major fluvial systems with a wide sloping interfluve in between. This interfluve has been greatly modified by fire. The occasional dead standing spar is a reminder of what once existed. *Gahnia*/wirerush-tangle fern scrub rushland now inhabits the area. In the lower half of the study area the induced forest margins form the study area boundaries.

Power Station Road provides access to the base of the study area. An overgrown track leads from Christmas Stream, near the old power station, climbing up the burnt interfluve through forest to the lake at 460 metres a.s.l.

The northwestern edge of the lake shows signs of human interference: the presence of a rock retaining mound suggests the lake has been raised slightly. There is an old jetty and building on the south east side of the lake. Two water channels run through the forest immediately behind the lake in a small area of modified low forest. Power poles and an old waterpipe line lead down from the lake, following the track for most of the way, to the derelict Fairdown power station at the base of the study area.

Mount Rochfort forest and much of the Denniston Plateau lie on tertiary Brunner coal measure parent material (Bowen 1964). These coal measures consist of medium to coarse quartz sandstone, grit, conglomerate, carbonaceous mudstone and coal seams (Nathan *et al* 1986). The soils have been broadly classified as upland and highcountry podzolised yellow brown earths and podzols; categorised as Denniston series above the lake and Millerton series below the lake (Soil Bureau 1969).

Westport airport is the nearest climate station. The recorded mean annual rainfall is 2192 millimetres. The mean annual temperature is 12.2°C with a daily average range of 7.3°C. February has the highest monthly temperature average of 16°C and July the lowest with 8.2°C (New Zealand Metereological Service 1983). However the climate changes considerably from Westport, on the coast, to the study area in the coastal ranges. There is a steep rainfall gradient from 2800 mm at the base of the study area to 6400 mm/year on average at the top (New Zealand Metereological Service 1978, Appendix 1). Fog can also shroud these ranges for many days at a time.

2.1.2. Comparative area: Mount Frederick

Care was taken to choose an area with similar topographical features to the main study area; in particular elevation, slope, and aspect. The area chosen in Mount Frederick State Forest had a similar elevational range to Mount Rochfort. Topographical features paralleled the main study area with a similarly even aspect, low sloped physiography in the top half of the area and more dissected, steeper physiography in the lower half.

The comparative study site is located approximately eight kilometres north east of Mount Rochfort forest on the same coastal range system (Fig 2.1). The Britannia walkway provides easy access to the base of this area.

This area is part of a deeply dissected hill system underlain by mainly indurated Greenland greywacke (Bowen 1964) of upper cambrian age (Cooper 1974) with precambrain Tuhua (Bowen 1964) in places at the base of the area. The soils have neen mapped as Wakamarama series upland and highcountry podzolised yellow brown earths and podzols (Soil Bureau 1969). The comparative area is a small part of a much larger intact forested hill system. The rainfall gradient is similar to the main study area (Appendix 1).

2.2. Field sampling

The main study area, at Mount Rochfort forest, was sampled in late December 1989 and early January 1990 in predominantly wet rainy conditions. The area was divided into 14 transect lines, 250 metres apart, running northeast/southwest (43^{o} and 225^{o} magnetic) perpendicular to the general relief of the area. The ends of each transect line were marked by the ridgeline boundaries running down slope. The first site on each transect line was located randomly with subsequent plot sites at 250 metre intervals until the other ridgeline boundary was met. 75 sites were sampled (Fig 2.4). The sample sites were permanently marked on aerial photographs (series SN8119 C/4 and B/3).

Field work for the comparative site was undertaken in mid March 1990 in similar weather. Two transect lines were initiated from Britannia Stream, at the base of the area, with plots sampled every 250 metres up the slope to the ridgeline. 17 sites were sampled and marked on the aerial photo SN8119 C/11.

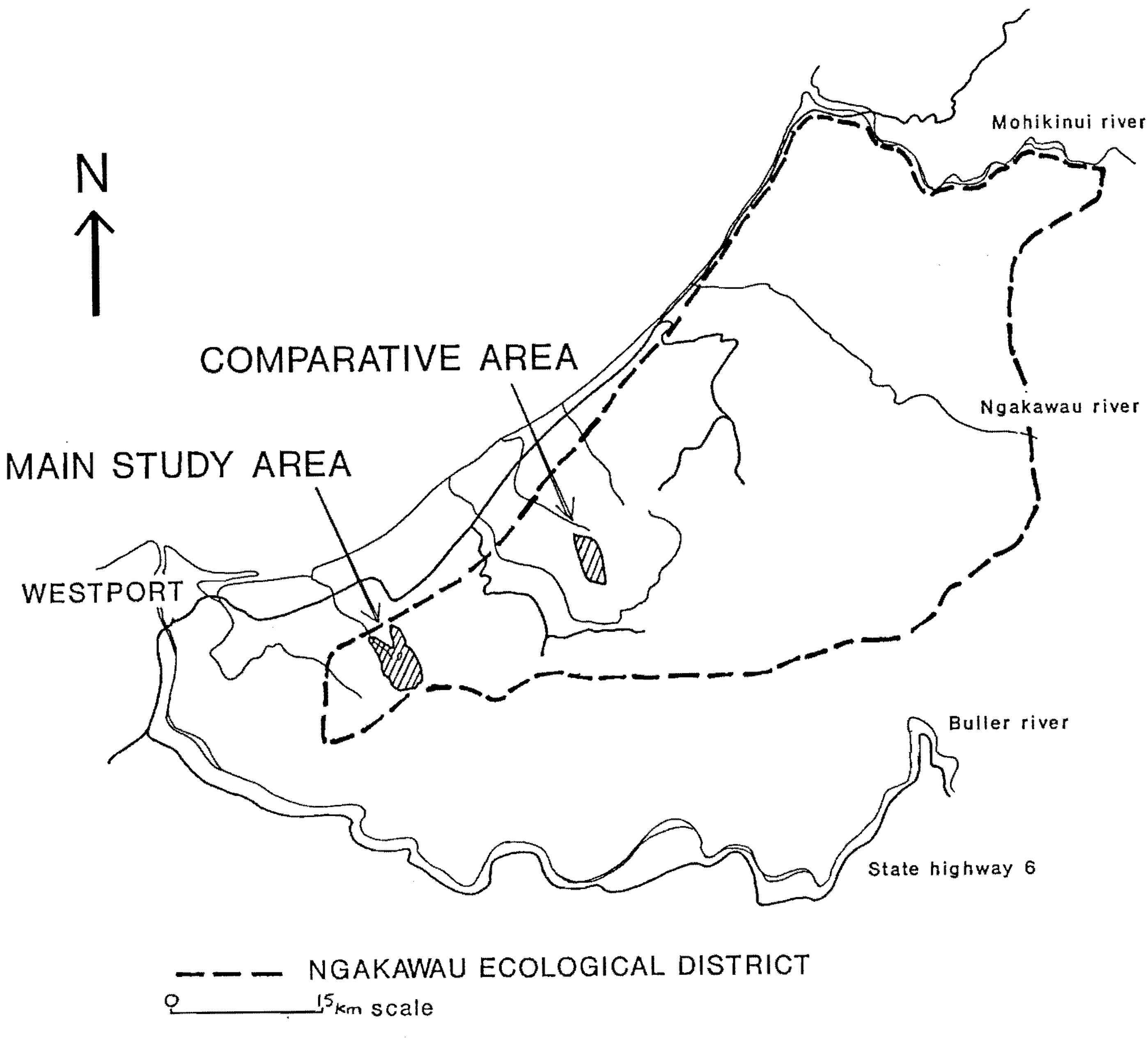

Fig 2.1 Map showing the distribution of the main study area, Mount Rochfort forest, and the comparative area at Mount Frederick state forest in the Ngakawau Ecological District.

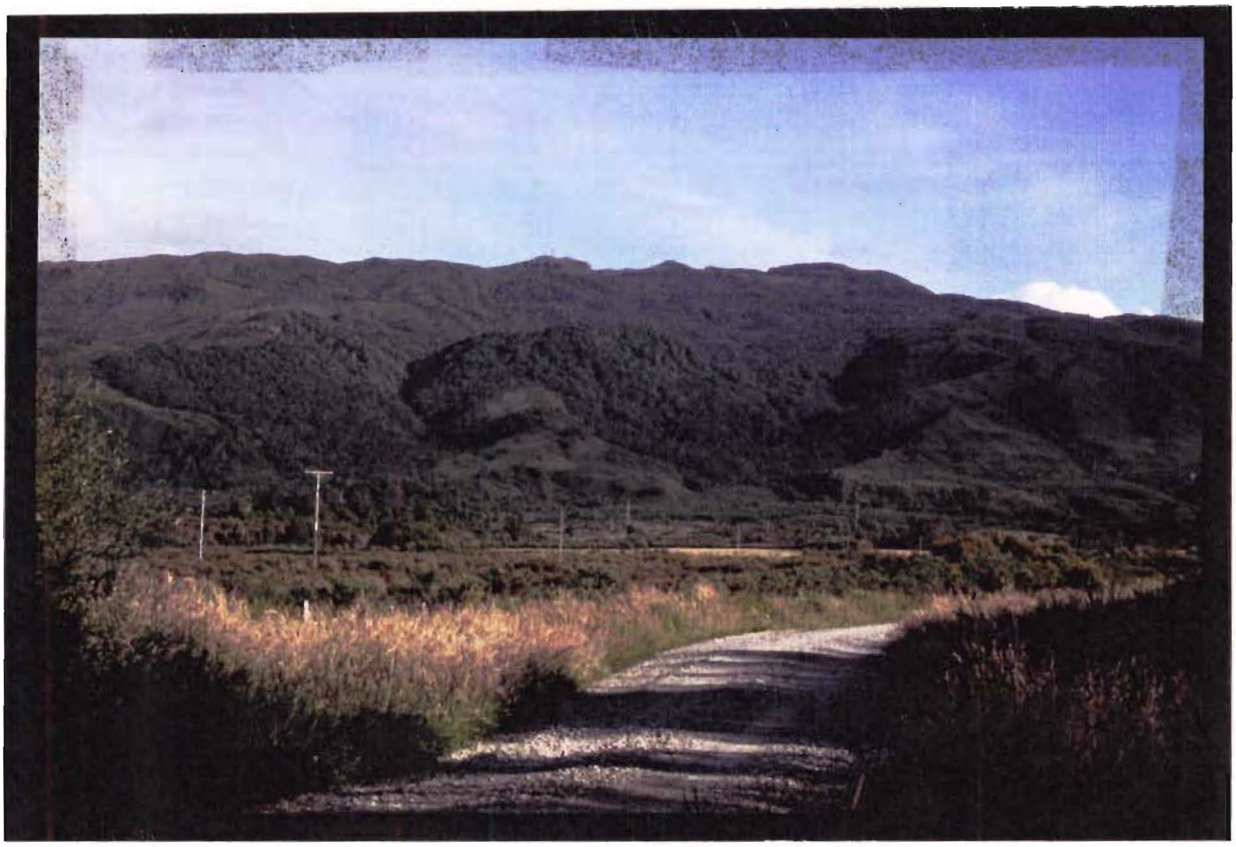

Fig 2.2 Photograph showing the main study area at Mount Rochfort.

Fig 2.3 Photograph showing the undissected topography above Lake Rochfort, Mount Rochfort forest.

At each plot site the reconnaisance plot procedure, based on methods by Allen & McLennan (1983), was used to record the structure and floristic composition of the vegetation. This is an unbounded method of sampling. Care was taken to ensure each site described contained topographical and vegetative homogeneity. The vegetation plot was divided into tiers. The emergent and canopy tiers had variable tier heights dependent upon the structure of each particular sample site. The remaining tiers were fixed at defined height intervals. The following tier and height distinctions were used:

Tier 1: Emergents (height range if present)
Tier 2: Canopy 12 metres to top height
Tier 3: 12 - 5 metres
Tier 4: 5 - 2 metres
Tier 5: 2 - 0.3 metres
Tier 6: 0.3 - 0.0 metres
Tier 7: Epiphytes

Within each tier each species present was recorded using a class system to represent percentage cover. Six different cover classes were used:

1: < 1%, **2**: 1-5%, **3**: 6-25%, **4**: 26-50%, **5**: 51-75%, **6**: 75-100%

Percentage ground cover of vascular plants, bryophytes, litter, exposed soil and rock fragments on the forest floor were estimated to the nearest 5%. The environmental factors; altitude, aspect, slope and drainage were also recorded at each site. Unfortunately drainage could not be recorded accurately due to the inclement weather during field work. Topographical features of the site and the surrounding area were described using the following landform classification system, broadly based on the Protected Natural Areas Programme landform classification system (see Kilvington *et al* 1990) and, checked by L. R. Basher DSIR. The four categories used are described as follows:

steppe: very low sloped landform
shoulder: rounded landform generally connecting steppes
and backslopes, or flanking ridgelines
backslope: steeper sloped landform
footslope: low sloped landform at the base of backslopes

A soil pit was dug at each site. A sample of the A horizon was collected for subsequent analysis.

2.3. Analysis

2.3.1. Vegetation

The vegetation plots were classified into communities on presence/absence using the polythetic divisive technique of indicator species analysis (ISA) implemented by TWINSPAN (Hill 1979). Divisions were examined and accepted at the third and fourth level for community classification. These communities were named following Atkinson (1985) which portrays community floristic and structural composition. In summary a (-) links two species in the same tier with the first species having greater cover. A (/) links two species from different tiers with the first species from a higher tier in the community. Common names are used in preference to scientific names due to simplicity and familiarity of use. In this study community naming included species with equal or greater than 15 percent canopy cover in their respective tier.

Major species compositional differences between community groups were best described using the technique of Stewart & Harrison (1987 p 386). This system used "indicator species": species with >40% frequency in one community and "at least 20% more frequent than in any other community or at least >20% frequent in one community and absent from all others". "Species groups", groups of species which have >40% frequency "in several communities and at least 20% more frequent in all of these than other communities", were also used to show florisitic differences.

2.3.2. Soils

Two pH readings were taken on each sample. Percentage of organic matter was calculated for each sample using a loss on ignition method. The percentage of organic carbon was calculated for each soil multiplying the percentage organic matter by 0.58 to enable comparisons with other studies. All soil analyses followed the methods of Nicholson (1984). Analysis of variance tests were performed, using SAS (version 6 Edition 1987), to examine whether pH and organic matter scores differed between parent materials and vegetation communities. Organic matter percentages were transformed by arcsine for these analyses.

2.3.3. Environmental data

Community, environmental and soil relationships were examined by the ordination technique of detrended correspondence analysis (DCA) using the programme CANOCO (version 2.1 Ter Braak 1988). Spearman's rank correlation analysis was performed to investigate the ranked DCA plot data and environmental relationships using STATISTIX (version 3.1 Analytical Software 1989).

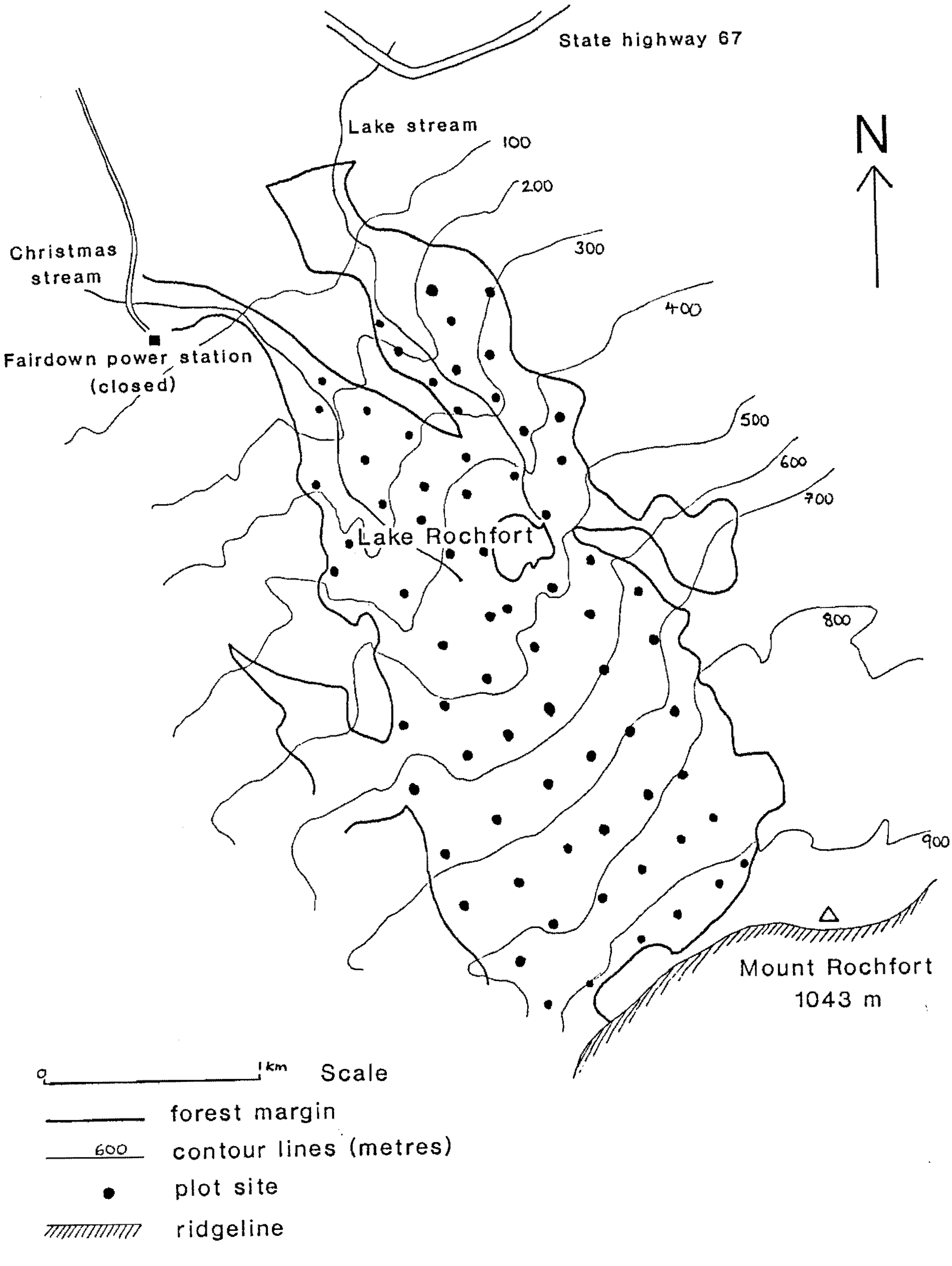

Fig 2.4 Map of main study area, Mount Rochfort forest, showing position of 75 plot sites.

3. RESULTS

138 species were recorded from the 92 vegetation plot descriptions. Only three species were not found at both study areas. The ground fern *Cyathea colensoi* was only recorded from Mount Frederick while *Libocedrus bidwillii* and *Astelia trinervia* were both found only at Mount Rochfort. *Gahnia pauciflora*, although not recorded within a vegetation description, was sited at Mount Rochfort forest in forest on the steep back slopes below Lake Rochfort. An average of 27 species was recorded per plot.

3.1. Plant communities

Six communities were recognised from 92 plot descriptions using ISA (Fig 3.1). Major community floristic differences were summarised using "indicator species" and "species groups" in Table 3.1. A full species list for each community is given in Appendix 2. Nomenclature follows Allan (1961), Moore & Edgar (1970), Brownsey *et al* (1985), and recent taxonomic changes listed in Connor & Edgar (1987) unless otherwise indicated (see appendix 3 for full species list). A brief description of each community follows with reference to Table 3.1.

1. Pink pine-mountain beech-yellow silver pine/*Gahnia* forest.

Ten indicator species separated this group from the remaining communities. Mountain beech (*Nothofagus solandri* var. *cliffortioides*) and pink pine (*Halocarpus biformis*) dominated the canopy of this stunted forest community (mean top height 5.25 metres, standard deviation 0.97 metres) with dense yellow silver pine (*Lepidothamnus intermedius*) in some sites. The shrub understorey was particularly dense dominated by the tall sedge *Gahnia procera* in association with yellow silver pine, manuka (*Leptospermum scoparium*), *Dracophyllum longifolium*, and pink pine (Fig 3.2). Although no one species dominated the forest floor the density of vegetation was reflected by the high percentage of ground vascular plant cover (Fig 3.3).

2. Mountain beech/*Astelia* forest.

This community was differentiated by five indicator species. Slightly stunted mountain beech and silver beech (*Nothofagus menziesii*) dominated the canopy with southern rata (*Metrosideros umbellata*) common as well. Gnarled *Quintinia acutifolia*, kamahi (*Weinmannia racemosa*) and *Archeria traversii* formed the subcanopy with *Dracophyllum traversii* common. *Astelia nervosa* dominated the shrub stratum in association with saplings of *Quintinia*, mountain toatoa (*Phyllocladus alpinus*), and *D. traversii* in conjunction with the sprawling *Metrosideros parkinsonii*. The forest floor of this community was exceptionally hummocky and mossy (Fig 3.3), partially or totally

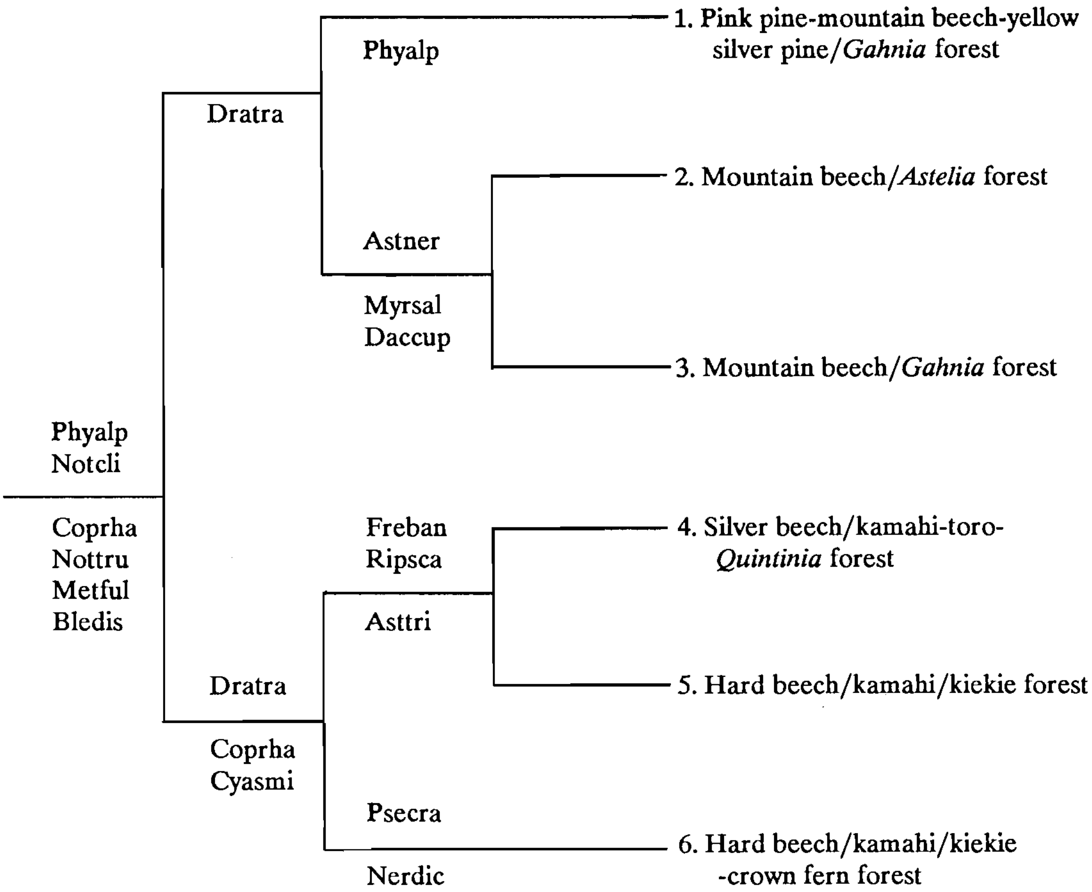

Fig 3.1 Dendrogram from ISA classification showing relationships between the 6 communities and the ISA indicator species identified at each division. The species codes are the first three letters of the generic and specific name for each species (see Table 3.1 for full names).

covering large (4 metres in diameter), coarse quartz sandstone boulders (Fig 3.4). In one area mountain cedar (*Libocedrus bidwillii*) replaced mountain beech in the canopy of this community.

3. Mountain beech/*Gahnia* forest.

Only one indicator species separated this community. It shared several species with a range of other communities. There were scattered rimu (*Dacrydium cupressinum*) throughout the mountain and silver beech canopy. Kamahi and *Quintinia* formed the subcanopy with toro (*Myrsine salicina*) providing a smaller component. These three species dominated the forest understorey. The shrub tier was dense, characterised by *Gahnia procera* and *Quintinia* with *Dracophyllum traversii*, mountain toatoa and *Metrosideros parkinsonii* common. The forest floor was undulating, and mossy with

Table 3.1 Percentage frequency of occurrence of "indicator species" and "species groups" in the communities. Percentage frequency is shown using the class system: 1, 1-20%; 2, 21-40%; 3, 41-60%; 4, 61-80%; 5, 81-100%. * follows Brownsey *et al* 1985.

	Community					
Species	1	2	3	4	5	6
Halocapus biformis	5	1	1			
Dracophyllum longifolium	5	1	1			
Cyathodes juniperina	5	1	1			
Leptospermum scoparium	5	1	1			
Lepidothamnus intermedius	4		2		2	
Phormium cookianum	4	1	2			1
Celmisia monroi	2					
Aporostylis bifolia	2					
Astelia linearis	2					
Lycopodium scariosum	2					
Astelia nervosa	3	5	1	3		1
Archeria traversii		5	3	2	2	
Pseudopanax simplex		4	2	1	1	1
Elaeocarpus hookerianus	2	4	2	1	1	
Coprosma pseudocuneata		3	1			
Tmesipteris tannensis	1	1	4	2	2	2
Earina autumnalis		1	2	4	2	2
Leucopogon fasciculatus		1	3	3	5	1
Astelia trinervia					4	2
Blechnum discolor		1		3	3	5
Coprosma grandifolia				1	3	5
Cyathea smithii				2		4
Blechnum "black spot"*			1	1	1	3
Carpodetus serratus				1		3
Pseudopanax linearis	4	5	2	1		
Nothofagus solandri	5	5	5		1	1
Pittosporum crassicaule	4	3	3		1	
Gahnia procera	5	2	4	1	1	1
Myrsine divaricata	1	4	3		1	
Metrosideros umbellata	5	5	5	5	4	2
Coprosma colensoi	3	4	3	3		
Grammitis billardieri	2	5	5	5	3	3
Dracophyllum traversii		5	5	4	5	1
Podocarpus hallii	2	2	4	4	5	1
Coprosma foetidissima	1	5	5	5	5	4
Nothofagus menziesii	1	5	5	5	5	4
Griselinia littoralis		3	3	4	3	3
Asplenium flaccidum		3	1	3	3	3
Myrsine salicina		1	5	5	5	5
Dacrydium cupressinum	2	1	5	4	5	4
Metrosideros fulgens			2	5	5	5
Nothofagus truncata			1	4	5	4
Prumnopitys ferruginea			1	4	5	4
Coprosma rhamnoides			1	4	5	4
Freycinetia baueriana			1		4	4
Ripogonum scandens					4	4
Dicksonia squarrosa					3	4
Hedycarya arborea					3	4

Fig 3.2 Community no.1: pink pine-mountain beech-yellow silver pine/*Gahnia* forest. (plot site P5).

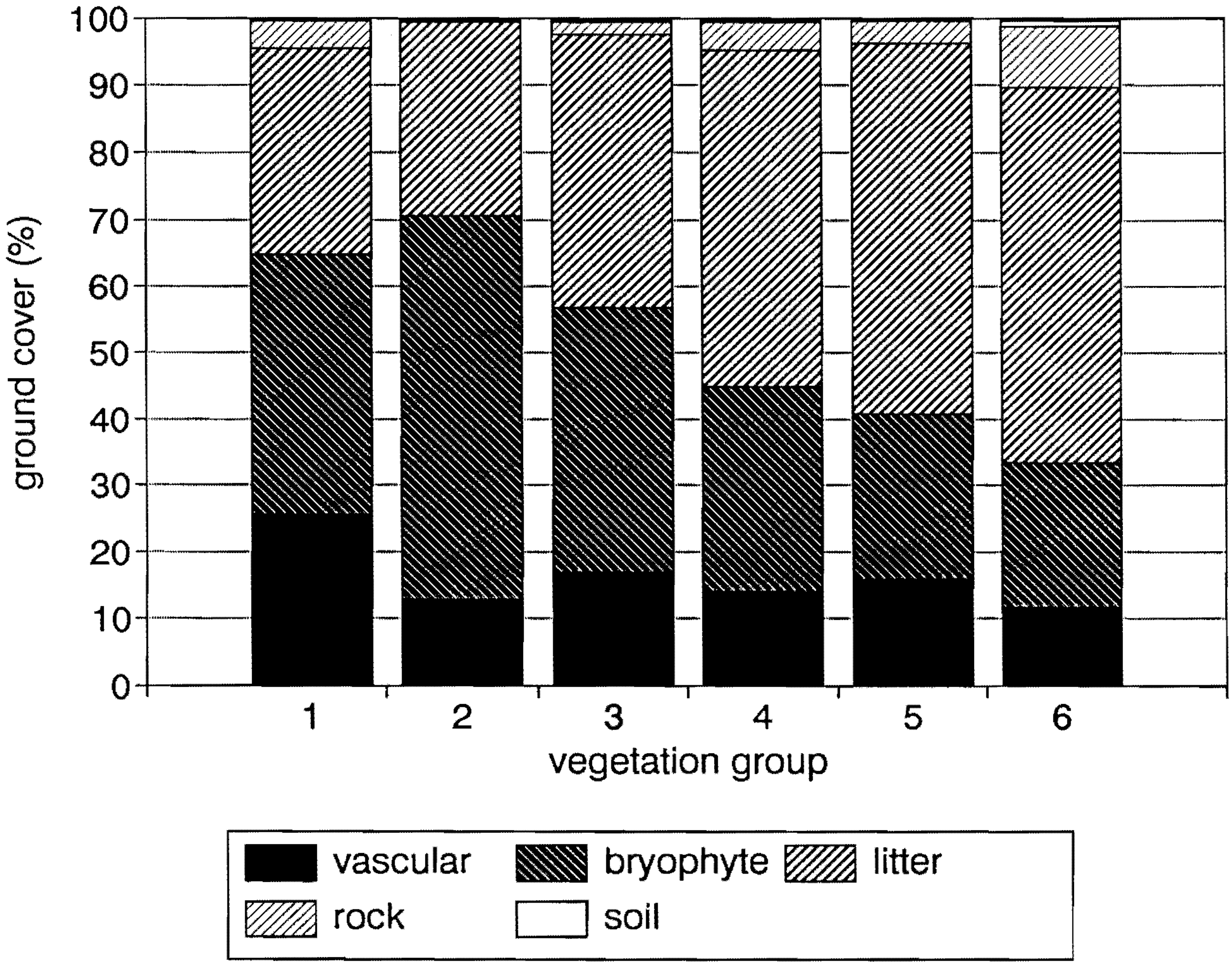

Fig 3.3 Percentages of forest floor ground cover for each vegetation community. Community names are given in the text.

Fig 3.4 Community no.2: mountain beech/*Astelia* forest. (plot site P6).

large quartz sandstone boulders common on the surface.

There was a distinctive subform of this community with dense yellow silver pine and mountain toatoa understorey cover.

4. Silver beech/kamahi-toro-*Quintinia* forest.

One indicator species separated this community from the others. It shared species with several species groups. Silver beech formed a closed canopy over a dense subcanopy of kamahi, toro and *Quintinia*. The latter three were common understorey species. The forest floor was characterised by dense *Quintinia* seedlings, the sedge *Gahnia procera* and the sprawling *Metrosideros parkinsonii*.

5. Hard beech/kamahi/kiekie forest.

This community was differentiated by two indicator species and shared species with a variety of different species groups. Hard beech (*Nothofagus truncata*) formed a closed canopy with silver beech, rimu and red beech (*N. fusca*) scattered throughout to limited extent. Kamahi dominated the subcanopy. Kamahi, toro and *Quintinia* were common in the understorey. Kiekie (*Freycinetia baueriana* ssp. *banksii*) dominated the shrub stratum with kamahi and *Quintinia* saplings, *Astelia trinervia*, crown fern (*Blechnum discolor*) and *Coprosma rhamnoides* common.

6. Hard beech/kamahi/kiekie-crown fern forest.

Five indicator species separated this community from the remaining five. There were two forms in this community. In one form emergent rimu overtopped the mixed canopy codominated by silver beech, red beech, and hard beech. There was a dense subcanopy of kamahi, and toro with *Quintinia* common. Hard beech dominated the canopy of the second form with Rimu scattered throughout. The subcanopy was more open than the first form, dominated by kamahi with toro common. *Quintinia* was not present with great abundance. Kamahi provided a dense subcanopy with toro common. Kamahi and toro dominated the understorey of both forms while kiekie and crown fern formed a particularly dense shrub stratum. Large quartz sandstone boulders were scattered throughout the forest floor of this community. Smaller rock fragments were also present on the floor in some plots (Fig 3.3).

Although not sampled, pole stands of kamahi, toro and *Coprosma grandifolia* were noted within this community.

3.2. Factors influencing community distribution and composition

3.2.1. Soils

pH scores varied between 2.98 and 4.28: 3.02 to 4.28 on coal measure parent material sites and 2.98 to 3.80 on greenstone greywacke (see Appendix 4 for full list). Analysis of variance tests found no significant differences between the two parent materials or any of the six vegetation communities (Table 3.2, 3.3).

Table 3.2 The mean pH levels and 95% confidence limits for plots on the two different parent materials, tertiary Brunner coal measures and upper cambrian Greenstone greywacke.

parent material	number of plots	lower 95% c. limit	mean	upper 95% c. limit
coal measures	75	3.461	3.528	3.595
greywacke	17	3.289	3.412	3.536

Table 3.3 Mean pH levels and 95% confidence limits for the six vegetation communities. Full community names are given in the text.

community	number of plots	lower 95% c. limit	mean	upper 95% c. limit
1	8	3.384	3.574	3.664
2	23	3.071	3.990	4.909
3	19	3.323	3.427	3.531
4	10	3.281	3.567	3.853
5	11	3.277	3.442	3.607
6	21	3.439	3.591	3.744

Percentages of organic matter ranged from 3.358 to 97.152 percent: 3.385 to 94.832 on coal measure parent material and 8.306 to 97.953 on greenstone greywacke (see Appendix 4 for full list). The analysis of variance tests, performed on transformed percentage scores, found no significant differences between the two parent materials or any of the vegetation communities (Table 3.4, 3.5). Organic carbon percentages ranged from 1.948 to 55.003 at Mount Rochfort and 4.817 and 55.653 at Mount Frederick (Appendix 4).

Table 3.4 Mean organic matter percentages and 95% confidence limits for the two different parent materials, tertiary Brunner coal measures and upper cambrian Greenstone greywacke.

parent material	number of plots	lower 95% c. limit	mean	upper 95% c. limit
coal measures	75	16.91	21.67	26.42
greywacke	17	22.63	38.60	55.17

Table 3.5 Mean and 95% confidence limits for the percentages of organic matter in the six vegetation communities. Full community names are given in the text.

community	number of plots	lower 95% c. limit	mean	upper 95% c. limit
1	8	1.779	14.52	27.26
2	23	18.00	30.99	43.98
3	19	10.13	19.91	29.68
4	10	6.670	25.59	44.72
5	11	8.193	16.27	24.35
6	21	17.28	28.78	40.28

3.2.2. Environmental variables and soils.

The ordination Axes 1 and 2 were used to plot the six vegetation communities (Fig 3.5). Significant correlations were found between DCA Axis 1 plot scores and elevation, landform, slope and aspect (Table 3.6). Plant communities were distributed in relation to altitude (Fig 3.6), landform (Fig 3.7), slope (Fig 3.8) and aspect (Fig 3.9). There were significant intercorrelations between these environmental variables along Axis 1 (Table 3.7). Thus low altitude steeply sloped plot sites occurred at the lower end of the DCA Axis 1 whereas the gentler sloping high altitude plots were distributed at the high end of this axis. Landform types were distributed along this axis from the low to high end as footslopes, backslopes, shoulders and steppes respectively. Plots at the lower end of Axis 1 had greater aspect variability than those at the high end of the axis (Fig 3.9) reflecting the contrasting landform types. The undulating northwesterly facing topography of the upper portion of Mount Rochfort forest contrasted with the steep dissected north to south facing backslopes below Lake Rochfort.

With environmental differences visible above and below Lake Rochfort subsequent analysis of variance tests were performed to examine whether pH and organic matter levels differed in the same manner. pH levels were, on average, 3.476 above the lake

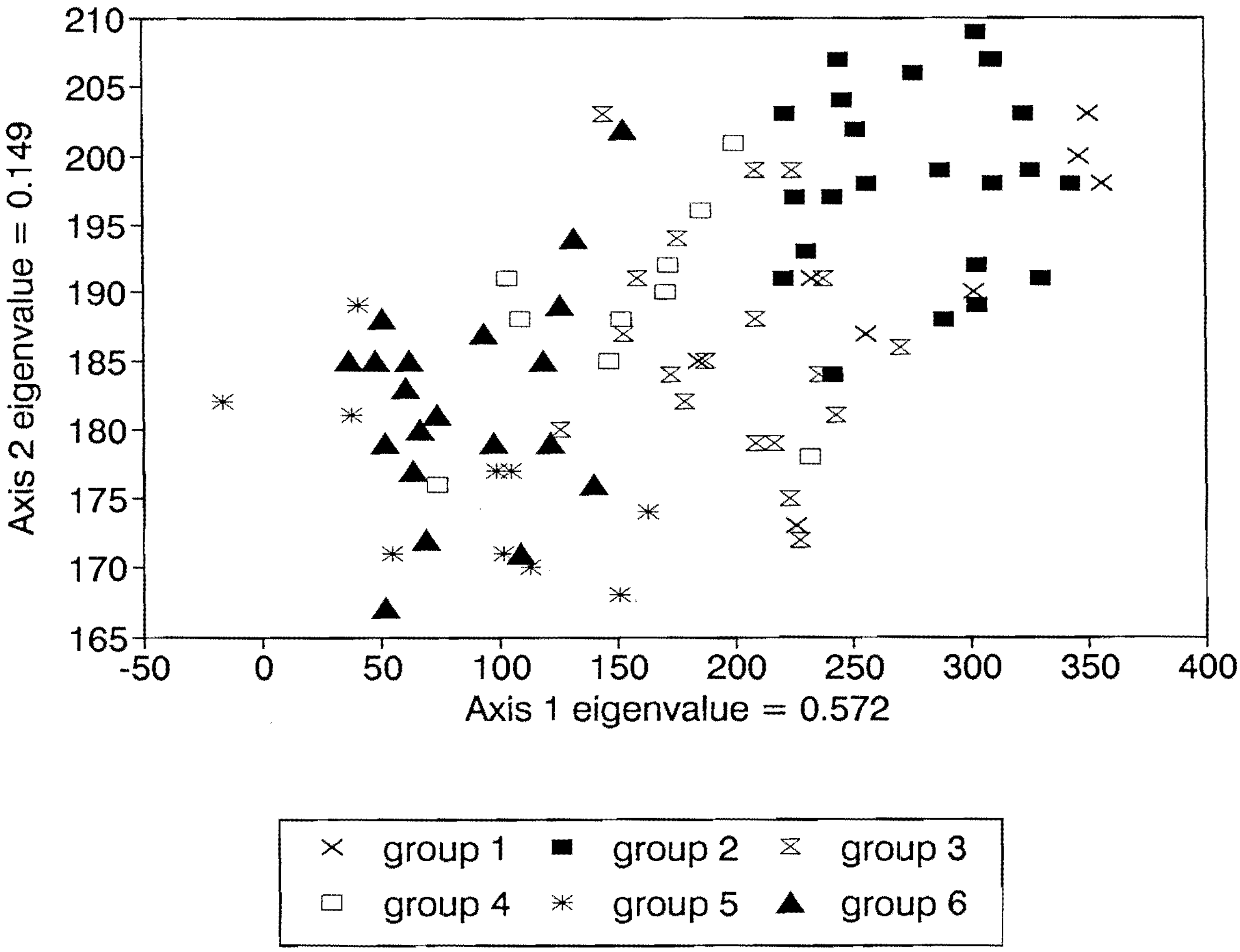

Fig 3.5 Scatter diagram of the 92 ordinated plot samples on DCA Axis 1 and Axis 2. Symbols recognise the 6 communities obtained from the ISA output. Community names are given the text.

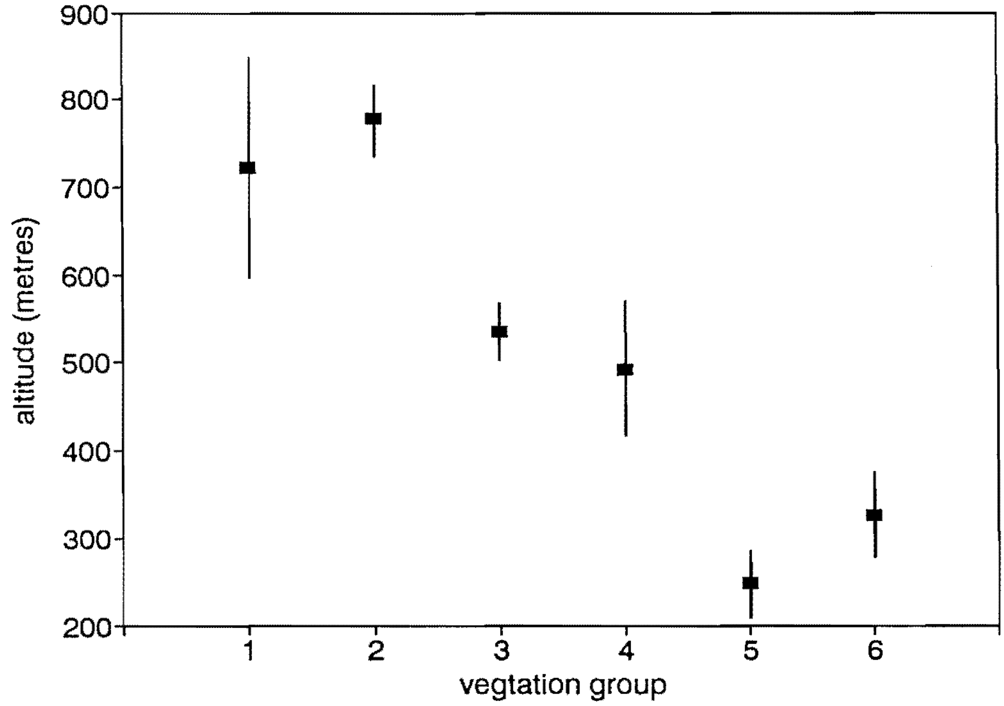

Fig 3.6 Mean elevational distribution of community groups (indicated by a square) with 95% confidence limits. Community names are given in the text.

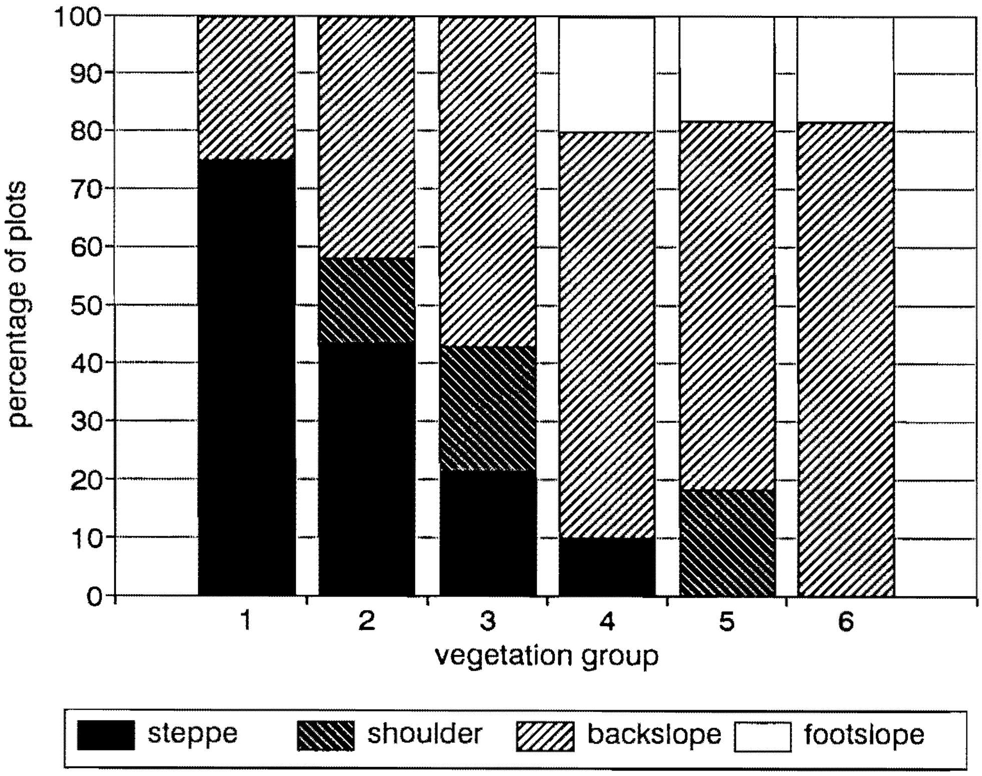

Fig 3.7 Percentage distribution of community groups by landform type. Community names are given in the text.

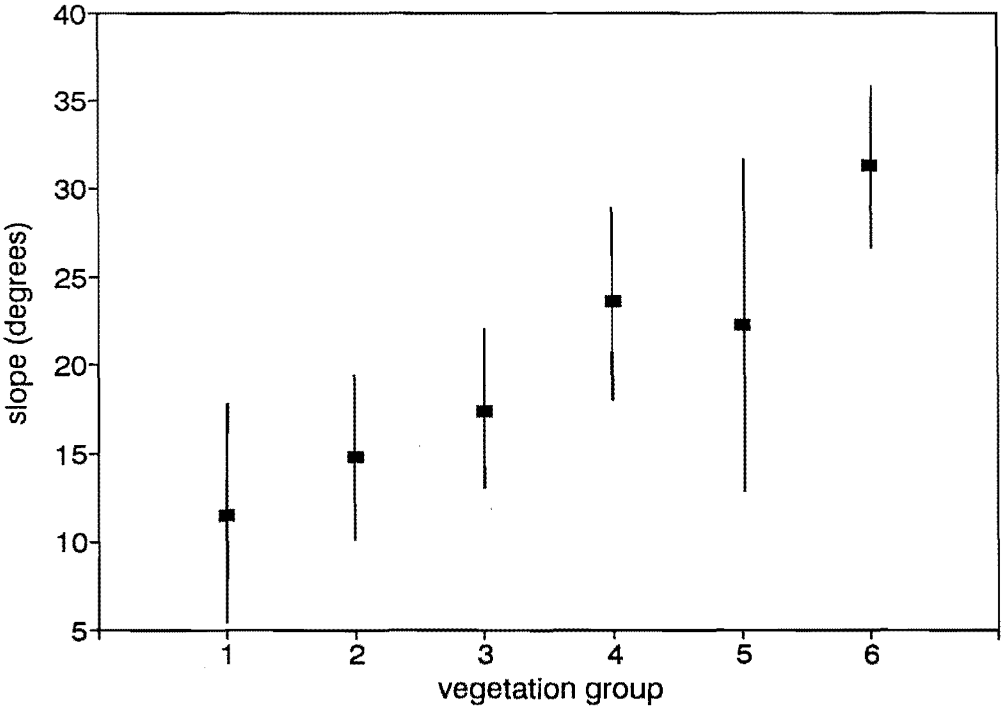

Fig 3.8 Community group mean slope (indicated by a square) and 95% confidence limits. Community names are given in the text.

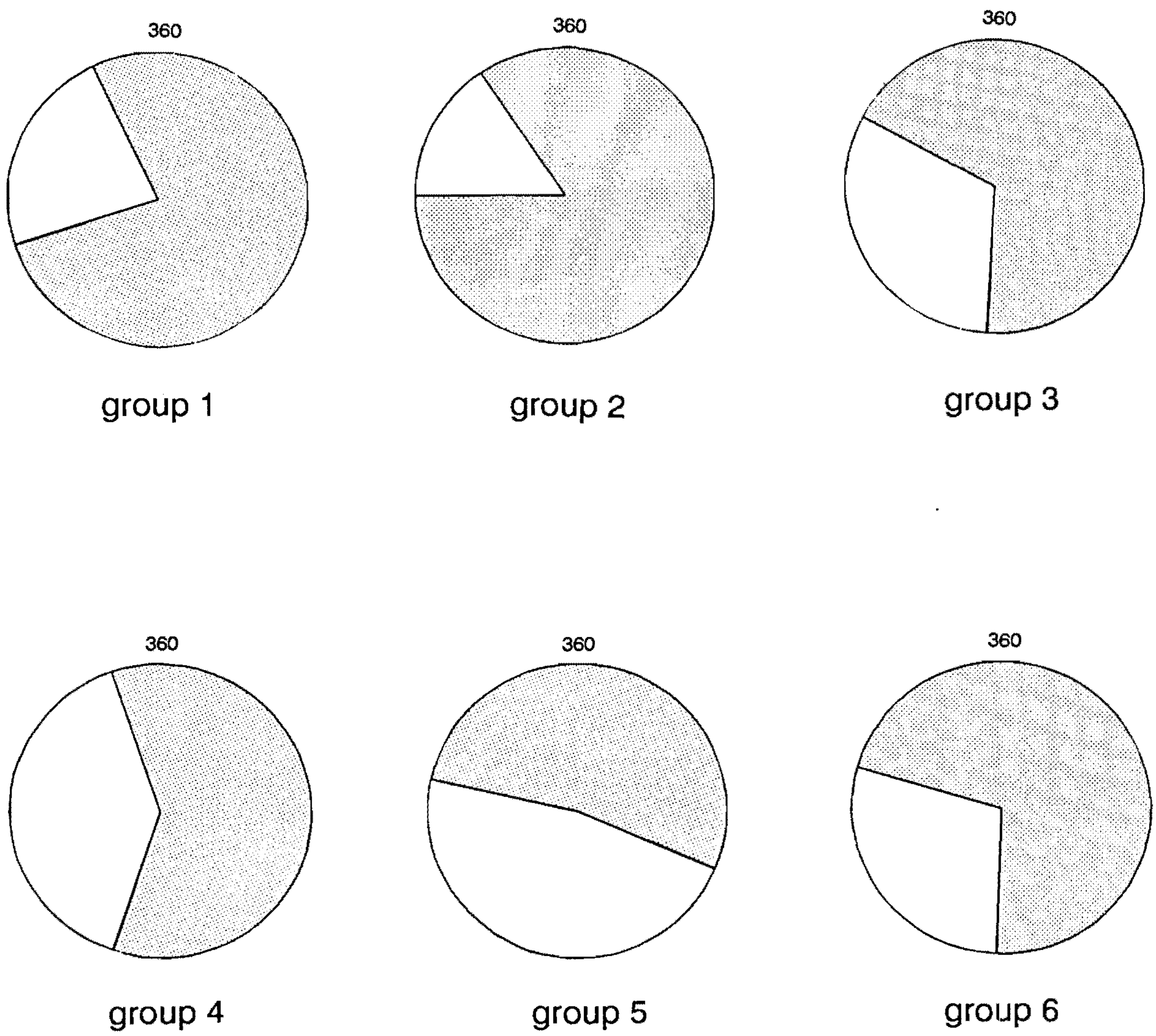

Fig 3.9 Diagram showing community group mean aspect and 95% confidence limits. The unpatterned area represents the upper and lower 95% confidence limit range with the mean aspect in the middle of this range. Community names are given in the text.

and 3.588 below and were not significant ($F=2.65$ $P>0.05$). Organic matter percentages were, on average, 26.66 above the lake and 20.66 below; these did not differ sigificantly ($F=0.23$ $P>0.05$).

Table 3.6. Spearman's rank correlation coefficients between plot ordination scores, environmental variables and soils. # eigenvalues for Axes 1 & 2 were 0.572 and 0.149 respectively.

variables	#DCA Axis 1	DCA Axis 2
Elevation	0.9419 **	0.8133 **
Aspect	0.3615 **	0.1369
Slope	-0.5663 **	0.0887
Landform	-0.7056 **	-0.1491
pH	-0.1158	-0.2918 **
Organic matter	-0.0939	0.2386 *

* * significant at $P<0.01$
* significant at $P<0.05$

Table 3.7. Spearman's rank relation coefficients between environmental variables significant in Axis 1 (eigenvalue of 0.572).

variables	Elevation	Slope	Landform
Aspect	0.3287 **	-0.2913 **	-0.2342 *
Landform	-0.5500 **	0.6136 **	
Slope	-0.3790 **		

* * significant at $P<0.01$
* significant at $P<0.05$

The ordination of DCA Axis 1 "indicator species" (Fig 3.10) reflected the influence of environmental variables on species distribution. Those characteristic of low altitude, steep dissected sites occurred at the left of Axis 1. Species from low sloping, mostly north west facing, high altitude sites above Lake Rochfort were at the high end of Axis 1.

The environmental information and distribution on DCA Axis 1 helped describe vegetation community distribution patterns. Pink pine-mountain beech-yellow silver pine/*Gahnia* forest (group 1) and mountain beech/*Astelia* forest (group 2) dominated the upper section of the forest above the lake. Pink pine-mountain beech-yellow silver pine/*Gahnia* forest formed low forest on shallow sloping areas (Fig 3.8), mainly on steppes (Fig 3.7), at the top of the study area. This community graded into mountain beech/*Astelia* forest on the slightly steeper sites. Pink pine-mountain beech-yellow silver pine/*Gahnia* forest also formed an area of forest centrally in the area above the lake and inhabited a small previously burnt patch immediately behind Lake Rochfort (Fig 3.11). Mountain beech/*Astelia* forest inhabited hummocky, mossy steppes and low sloping backslopes (Figs 3.3, 3.7, 3.8) in the upper half above Lake Rochfort (Fig 3.11).

There was a distinct difference between the altitudinal distribution of groups 2 and 3 (mountain beech/*Gahnia* forest) (Fig 3.5). Mountain beech/*Gahnia* forest dominated the lower half of the area above Lake Rochfort and the shoulder surrounding the lower edge of the lake. One form of this community, with a dense yellow silver pine and mountain toatoa understorey, tended to inhabit flatter slopes than the community in general. This form graded in to the low pink pine-mountain beech-yellow silver pine/*Gahnia* forest in the centre of the area above the lake (Fig 3.11).

The remaining communities were predominantly or totally distributed on the dissected slopes below Lake Rochfort (460 metres a.s.l) (Fig 3.7). Above the lake silver beech/kamahi-toro-*Quintinia* forest (group 4) formed a distinctive band on moderate slopes at the base of the steep scarp along the north east boundary of the study area. There was also a small patch below the slopes of the adjacent south west boundary. This group was distributed on the moderately steep upper slopes below Lake Rochfort (Fig 3.11). The other community inhabiting moderate slopes, hard beech/kamahi/kiekie forest (group 5), was distributed in the lower half of the area below Lake Rochfort. It formed a distinct community on backslopes to the true right of Lake Stream (Fig 3.11).

The remaining community, hard beech/kamahi/kiekie-crown fern forest (group 6), occurred on steep backslopes below the lake. The silver beech variant of this community inhabited steep, dissected slopes in the upper half of this area as well as the steep scarp face on the northeast boundary above the lake. The hard beech dominated variant occurred on lower altitude backslope sites (Figs 3.11, 3.12). Some instability was noted in this forest community particularly on slopes flanking streambeds. In these places recent slip sites supported little vegetation while older slip sites were inhabited by pole broadleaf communities.

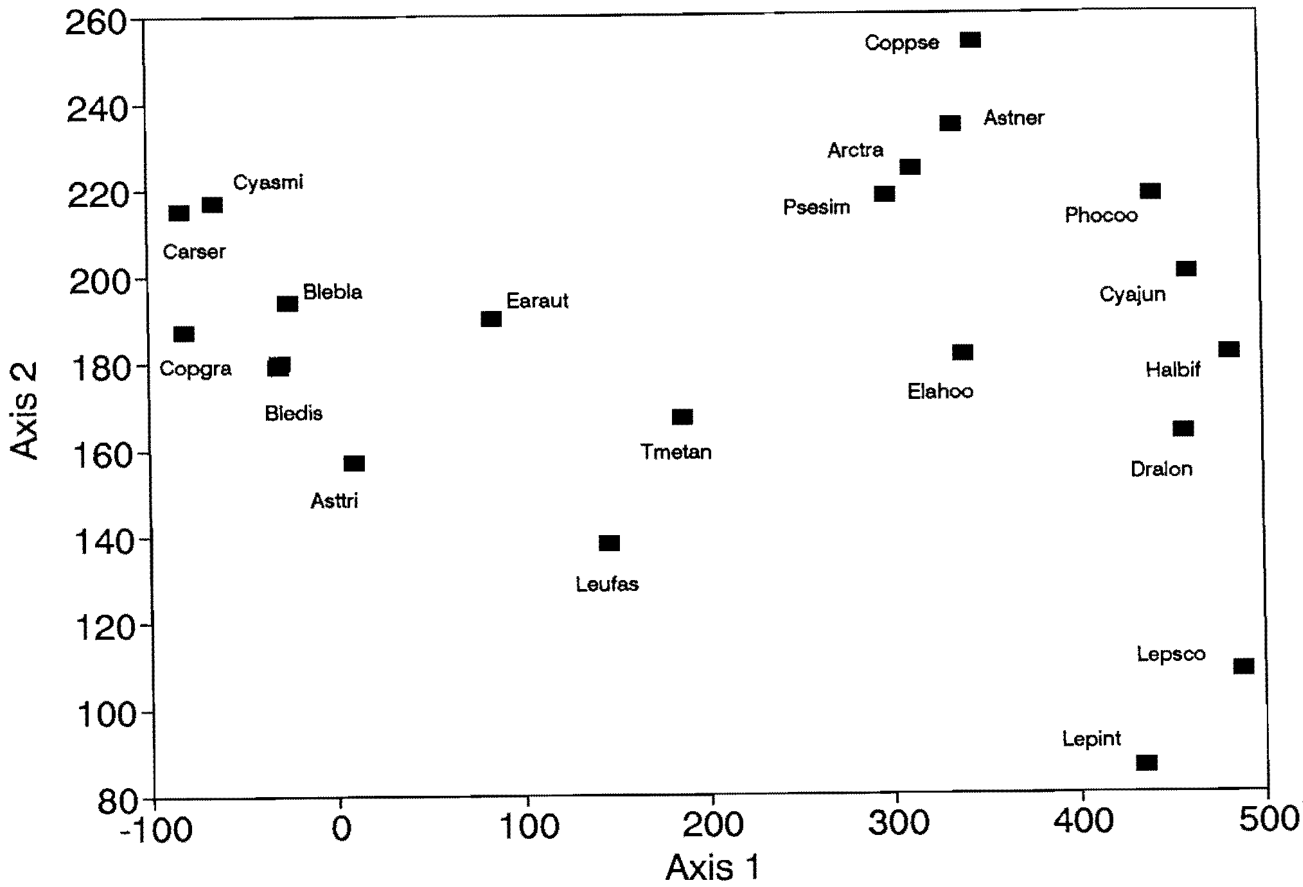

Fig 3.10 Scatter diagram of ordinated "indicator species" scores, from Table 3.1., on Axis 1 and Axis 2. Species codes are the first three letters of the generic and specific name for each species. See Table 3.1 for full list of "indicator species" names.

Fig 3.11 Vegetation map of Mount Rochfort forest showing the distribution of the 6 communities identified. Mapping was based on plot data and aerial photos. The mapped communities are: **1**, pink pine-mountain beech-yellow silver pine/Gahnia forest; **2**, mountain beech/*Astelia* forest; **3**, mountain beech/*Gahnia* forest; **4**, silver beech/kamahi-toro-*Quintinia* forest; **5**, hard beech/kamahi/kiekie forest; **6**, hard beech/kamahi/kiekie-crown fern forest.

3.3. Vegetation community distribution between the 2 study areas

All six communities identified by ISA were present in the Mount Rochfort forest with the plots from Mount Frederick distributed throughout five of the six communities (Table 3.8).

Table 3.8 Table showing distribution of the 92 plots from the two study areas, Mount Rochfort and Mount Frederick, throughout the six communities. Community names are given the text.

community	total plot number	plots at Mt. Rochfort	plots at Mt. Frederick
1	8	7	1
2	23	16	7
3	19	18	1
4	10	7	3
5	11	11	0
6	21	16	5

The average number of species per plot differed very little between vegetation descriptions from the two parent materials (Table 3.9).

Table 3.6 Mean species and 95% confidence limits for vegetation descriptions on the two parent materials, tertiary Brunner coal measures and upper cambrian Greenstone greywacke.

parent material	lower 95% c. limit	mean	upper 95% c. limit
coal measures	26.00	27.35	28.71
greywacke	23.47	25.59	27.71

4. DISCUSSION

4.1. Influences on community distribution at Mount Rochfort

The distribution of vegetation at Mount Rochfort forest was influenced by altitude, landform type, aspect and slope. These influences have been documented in detail by only two other West Coast hillslope studies (Basher 1986, Stewart & Harrison 1987).

Six community groups were distinguished and were broadly divided in two by Lake Rochfort with three distributed above the lake and three below. Of those above the lake; pink pine-mountain beech-yellow silver pine/*Gahnia* forest, (group 1), inhabited low sloping steppes in the top of the study area with mountain beech/*Astelia* forest, (group 2), distributed below this on slightly steeper, hummocky slopes. Mountain beech/*Gahnia* forest, (group 3), occurred on steeper slopes immediately above the lake (Fig 3.11).

In contrast the topography below the lake was steeper and more dissected with greater aspect variability (Fig 3.9). Silver beech/kamahi-toro-*Quintinia* forest, (group 4), dominated moderately sloped backslopes immediately below the lake with hard beech/kamahi/kiekie forest, (group 5), on the moderate slopes towards the base of the area. The two forms of hard beech/kamahi/kiekie-crown fern forest, (group 6), were distributed on the steep backslopes in the lower half of the study area.

Separation by Lake Rochfort was also reflected by the species distribution. Twinspan division one ISA indicator species showed this split (Fig 3.1). Mountain beech, the dominant canopy species above Lake Rochfort, was present in groups 1, 2, and 3. In contrast hard beech, a major canopy species below the lake in groups 4, 5 and 6, occurred with low frequency in the three communities above the lake (Fig 3.1, Table 3.1). Other division one indicator species; mountain toatoa, *Metrosideros parkinsonii* and *Myrsine divaricata* were present only above the lake where as *Metrosideros fulgens* and *Coprosma rhamnoides* occurred below. Other "species groups" in Table 3.1 showed further differences between groups 1, 2, 3; and 4, 5, and 6.

The split between groups 1, 2, 3 and 4, 5, 6 was the most distinctive community separation on the DCA ranked plot ordination diagramme (Fig 3.5). The overlap of community groups suggests that vegetation change was a continuum rather than distribution into separate distinct groups. This was reflected by species affinities between several different communities (Table 3.1). Better explanation of Axis 2, with information not collected in this study, may separate the communities into more distinct groups.

Other unrecorded environmental variables may further explain community distribution along DCA Axis 1; for example drainage which unfortunately could not be measured. Topographical differences above and below the lake suggests that the drainage ability of low sloping landforms in the top half of the study area differed markedly to the steep backslopes below the lake. A west Nelson study found that mountain beech and mountain beech/silver beech forests were more frequent on low sloping poorly drained sites (Rose 1985); these correspond to communities above Lake Rochfort. A central Westland study, at Camp creek, showed that species distribution reflected differences in drainage. Pink pine, *Gahnia procera* and *Pseudopanax linearis* inhabited poorly drained soils; whereas *Coprosma rhamnoides*, crown fern, *Cyathea smithii*, *Hedycarya arborea* and *Dicksonia squarrosa*, for example, occurred on well drained soils (Stewart & Harrison 1987). At Mount Rochfort the distribution of these particular species, as shown on the species ordination diagramme (Fig 3.10), suggests that Axis 1 may also have reflected a change from well drained, low altitude sites to poorly drained, high altitude sites from left to right along this axis. The overriding rainfall gradient running parallel to the altitudinal gradient must also be kept in mind (New Zealand Metereological Service 1978). Accordingly communities above the lake would be subjected to much wetter conditions. Changes in altitude, causing changes in temperature, may have also influenced species distribution (Wardle 1964).

A similar altitudinal floristic separation was found in west Nelson. Forests below 950 metres a.s.l were dominated by red beech, southern rata, kamahi, and *Quintinia* with understorey species such as *Carpodetus serratus*, *Coprosma rhamnoides*, and *Aristotelia serrata*. In contrast forests above this altitude were dominated by mountain beech with species such as *Dracophyllum longifolium*, *Coprosma pseudocuneata*, *Archeria traversii*, and *Hebe cantaburiensis* common shrub and understorey species (Rose 1985). Walls & Laffin (1986) identified three distinct altitudinal changes in forest composition on the hillslopes of the Marlborough Sounds. Hard beech dominated the forest below 500 metres with red beech forest midslope (500 - 700 metres) and silver beech forest above 700 metres.

In contrast Stewart & Harrison (1987), at Camp creek in a central Westland mountainous basin, found that altitudinal distribution of species was strongly influenced by surface stability and soil development. Seral communities, for example broadleaf-*Hebe* forest, inhabited recent soils on landforms subject to frequent disturbance while mature communities, for example kamahi-rata-*Quintinia* forest, occurred on well developed soils on stable surfaces. This study identified a broad spectrum of surface mass movement types; for example frequent deposition, episodic erosion, and slow, continual creep. Mass movement was influenced by uplift, due to the close proximity of the Alpine fault, and high rainfall. Conversely vegetation communities at Mount Rochfort did not reflect major surface instability. No seral communities were classified. There were subtle indications of small land movement. Most of the large quartz sandstone boulders scattered through the bush appeared to be colluvial in origin. There were signs of recent erosion and pole stands of kamahi, *Quintinia acutifolia*, and toro noted in hard beech/kamahi/kiekie-crown fern forest below the lake. In some areas the forest floor of this vegetation community was particularly unstable, with more or less running shingle, suggesting that regular slope movement may take place beneath the present vegetation community. Detailed soil profile analysis has been used to determine the history of landform stability and the age of the soils (Harrison 1985, Stewart & Harrison 1987). Basher *et al* (1988) found, in the Cropp Basin, central Westland, that landform stability related to the structure of underlying parent material. Changes in the morphological and chemical properties of soils have been shown to occur with increasing soil development (Smith & Lee 1984).

4.2. Comparison with other vegetation studies on coal measures

4.2.1. North west Nelson

There were some obvious differences between Mount Rochfort forest and the study of vegetation on coal measures by Rogers (1982), at Mount Burnett, in north west Nelson. The latter area had been modified to some extent by logging and damaged by goat, deer and possum browse. The Mount Burnett area had virtually no altitudinal range (500 to 585 metre range) (Rogers 1982). In contrast Mount Rochfort forest was intact, with no apparent damage by browse and a significant elevational range.

Rogers (1982) described coal measure vegetation community patterns by physiographic position. Low sloping, strongly gleyed ridge and shoulder sites were inhabited by low, open, structurally simple forest dominated by yellow silver, pink and silver pine, mountain beech and southern rata. Understorey species included mountain toatoa, kanuka (*Kunzea ericoides*), manuka, *Dracophyllum townsonii*, *Gahnia procera*, and *Blechnum latifolium*. Mountain cedar rose emergent above this community on shoulder sites (Rogers 1982 pp 26, 33, 130). This community had closest affinity with Mount Rochfort groups 1 and 3.

The mid slope forests on steep (30 degrees), poorly drained, moderately gleyed podzols supported tall podocarp beech forest which comprised of rimu, mountain cedar, hard beech, silver beech and southern rata, over *Elaeocarpus hookerianus*, toro, and kamahi, with a shrub layer of *Astelia trinervia*, *Quintinia serrata*, *Gahnia procera*, *Cyathodes juniperina*, *Uncinia rupestris* and *Blechnum latifolium* (Rogers 1982 p 133). This community showed some association to group 5 at Mount Rochfort but contained species more characteristic of communities on the flatter slopes above the lake; for example *Gahnia procera*, and mountain toatoa.

The third coal measure community at Mount Burnett inhabited flat, poorly drained, moderately gleyed podzols at the base of a gully. Mixed pink, yellow silver and silver pine dominated the canopy with emergent rimu and mountain cedar present. Mountain toatoa, toro, kanuka, *Gahnia procera* and *G. xanthocarpa* inhabited the forest floor (Rogers 1982 pp 23, 132). This community had no close affinities to any Mount Rochfort community.

Fewer communities were recorded at Mount Burnett and those, to some extent, showed similarities with Mount Rochfort communities above Lake Rochfort. Silver pine and mountain cedar, dominant species at Mount Burnett had very limited abundance and distribution at Mount Rochfort. Most of the species present in the lower altitude vegetation groups at Mount Rochfort were not recorded at Mount Burnett.

4.2.2. North Tararanki

Bayfield (1986) described a number of different forest communities in the lowland Mokau coalfield area of north Taranaki. Communities were mostly dominated by tawa (*Beilschmiedia tawa*) and showed little affinity to communities present at Mount Rochfort. However one, hard beech forest, which inhabited very steep slopes had similarities with groups 5 and 6. This community had a hard beech canopy with an understorey of Kamahi, *Quintinia serrata*, *Dracophyllum latifolium* and scattered crown fern (Bayfield 1986).

4.2.3. Mount Rochfort communities in relation to the rest of the Ngakawau Ecological District

Analysis from the present study has provided a more detailed description of forest community patterns at Mount Rochfort forest than Kilvington *et al* (1990).

However the communities in the present study related to those identified by Kilvington *et al* (1990). Group 1, pink pine-mountain beech-yellow silver pine/*Gahnia* forest, corresponded to a reduced form of mountain beech/yellow silver pine-pink pine forest identified on other disturbed coal measure coastal slopes to the north of Mount Rochfort forest (Kilvington *et al* 1990). Group 2, mountain beech/*Astelia* forest, had closest affinities with rata-mountain beech forest. This latter group inhabited plateaux gullies and formed a montane belt on Mount William in the centre of the District (Kilvington *et al* 1990). The combination of groups 2 and 3, mountain beech/*Gahnia* forest, had some similarity to mountain beech-silver beech forest described by Kilvington *et al* (1990). This forest covered extensive areas on the western slopes of Mount Willliam and was also another plateaux gully community (Kilvington *et al* 1990). No community resembled groups 4 and 5. Group

6, hard beech/kamahi/kiekie-crown fern forest had loose affinities with rimu/broadleaf forest, identified at low altitudes on coastal hillslopes and the fluvial systems of Mount Frederick State Forest and the Orowaiti catchment. The forest floor of this community was densely covered by kiekie and supplejack (*Ripogonum scandens*) but the canopy was dominated by kamahi with emergent northern rata (*Metrosideros umbellata*) (Kilvington *et al* 1990) which was absent in the Mount Rochfort study area.

Thus the communities above Lake Rochfort had links with similar communities on the plateaux while those below the lake differed from other forest groups previously identified. This may relate to limited sampling of coastal hillslopes by the previous survey. It may also reflect differences in temperature and rainfall between the previously sampled front coastal slopes and the comparative study site, in this study, located further inland within the Mount Frederick State Forest hillslope system.

4.3. The influence of parent material and soils on community distribution

4.3.1 The vegetation

Results from the present study indicate that vegetation distribution was little influenced by parent material. The 17 plots from the Greenland greywacke Mount Frederick site were distributed throughout five of the six communities identified at Mount Rochfort.

Other studies have shown that parent material can influence forest vegetation distribution. A west Nelson study found major forest types distributed in relation to the underlying parent material fertility. However this also paralleled a rainfall gradient (Rose 1985) of similar magnitude to the Mount Rochfort area (Davis 1985). Forest communities on the hillslopes of the Inangahua Depression, north Westland, were differentiated by parent material. Slopes underlain by Old Man Gravels were dominated by hard beech rimu forest whereas hillslopes from a muddy sandstone parent material supported red beech hard beech forest (Mew 1975).

Rogers (1982) showed that parent material influenced species distribution. Several species were restricted to coal measures; mountain beech, *Pittosporum rigidum*, yellow silver pine, *Gahnia procera*, *Dracophyllum townsonii* and *Cyathodes juniperina*. These were a similar group to those dominant above Lake Rochfort. This probably corresponds to similarities in altitude and possibly drainage. However Rogers' "strictly calcareous" species; for example *Elaeocarpus hookerianus*, *Neomyrtus pedunculatus*, *Astelia nervosa*, and *Pseudopanax crassifolius* were also abundant at Mount Rochfort.

Forest complexity, total foliar cover and species richness increased with parent material fertility (Rose 1985). Rogers (1982 p91, 129) observed a similar trend with a greater mean number of species on calcareous parent material than on coal measures.

4.3.2. Soils

Analyses showed no significant difference in soil pH levels or percentages of organic matter between coal measures and greenstone greywacke parent materials, or between different vegetation groups. The pH results of the present study showed that soils of both parent materials were highly acidic (Appendix 5).

Palmer (1985) found, in west Nelson, that undeveloped soils showed differences in parent material. However soil fertility of high country podzolised yellow brown earths and podzols did not reflect parent material differences. These soils, in similarity to Mount Rochfort, were the most common soil types in the western high rainfall area of the west Nelson study. The top and subsoil pH values of all these soils were highly acidic. High rainfall overides any effects of parent material differences (L. R. Basher pers. comm.). In high rainfall conditions soluble elements and compounds are leached through the soils regardless of parent material (Mew 1975). This may explain why the "strictly calcareous" species of Mount Burnett inhabited the coal measures of Mount Rochfort.

Under Westlands high rainfall soils increase in acidity and decrease in drainage with rapid development to gley podzols (Stewart & Harrison 1987). It has been shown that slope and surface stability, i.e landform, greatly influence soil development and hence fertility under high rainfall conditions. For example unstable sites maintain recent soils with higher fertility (Palmer 1985, Stewart & Harrison 1987). Fertility remains low once a certain stage of soil development is reached (Stewart & Harrison 1987). In this way, at Mount Rochfort, insignificant pH differences between vegetation groups suggest that instability was not a major component of this area, or that the soils were all of a similar developmental stage, or were past the point when differences in fertility could be detected.

Studies in lower rainfall areas have shown contrasting results. Rogers (1982), in a 2000 mm/year rainfall area, found coal measure soils much more acidic (pH 3.98-5.06) than marble, dolomite and schist soils (pH 4.94-7.62). Walls & Laffin (1986) indentified nutrient differences between siliceous and basic parent material soils. They also found that in higher rainfall areas soils had lower nutrient levels in comparison to similar soils of the same parent material in drier conditions.

The pH results from Mount Rochfort indicated more acidic soils than the weakly gleyed yellow brown earths (pH 4.5) and gley podzols (4.1) studied by Palmer *et al*

(1986) under similar rainfall conditions, near Moeraki south Westland, on paleozoic indurated greenland greywacke. Results from west Nelson indicated less acidic soils than at Mount Rochfort. pH levels ranged from 4.1-5.0 in highcountry yellow brown earths, 3.8-4.0 in high country podzols, to 4.1-4.6 in highcountry gleys and podzolised gley soils (Palmer 1985). Rogers (1982 p 110) recorded a less acidic A horizon pH range for soil overlying coal measures (3.98 to 5.06) than was present at Mount Rochfort.

Soil percentages of organic carbon were extremely variable from very low percentages to very high levels (Appendix 4, Appendix 5). The percentage level did not relate to vegetation grouping, distribution above or below Lake Rochfort, or correlate with any environmental variable. At Mount Rochfort carbon percentages were higher in relation to the pH levels than soils measured in south Westland; at Moeraki (Palmer *et al* 1986), on MacFarlane Mound and Nisson Hill (Mark & Lee 1985). Mark & Lee (1985) found high carbon levels, similar to some of the highest recorded at Mount Rochfort, in flat poorly drained rimu kamahi swamp forest at the base of MacFarlane Mound. However pH levels at Mount Rochfort were much more acidic and plot sites with high carbon levels ranged from almost flat to very steep (>30 degrees).

More detailed analysis of other soil factors may show different stages of soil development at Mount Rochfort. Smith & Lee (1984), in the Arawata valley south Westland, found that with increasing surface age and soil development organic carbon levels built up in conjunction with increased cation exchange and exchangeable magnesium, calcium, potassium and sodium. In contrast pH levels, total nitrogen and available phosphorous all decreased.

4.4. Conclusions

The vegetation patterning at Mount Rochfort was complex. There were gradual changes in composition with the most definitive separation by Lake Rochfort in the centre of the area. The indistinctness of community boundaries reflected the number of intercorrelating environmental variables influencing along the same gradient axis; altitude, slope, landform, and aspect; and the overriding rainfall gradient. Other unmeasured influences, for example drainage and temperature, also appeared to influence species composition along the same axis.

Soil analysis showed no parent material or vegetation community differences in this study. However more detailed profile descriptions and chemical analysis may show developmental differences.

Mount Rochfort forest encorporated a significant altitudinal range from lowland to subalpine forest which no other coal measure study has documented. Its acidic soils supported a more diverse range of species than other studies have identified.

The upper part of the Mount Rochfort altitudinal sequence brought together forms of several communities which have been identified separately in the Ngakawau Ecological District on the Denniston and Stockton plateaux. However communities in the lower half below Lake Rochfort differ from those previously recorded. With an elevational range of approximately 900 metres Mount Rochfort forest supported a diverse range of species no longer represented elsewhere on coal measures in the Ngakawau Ecological District nor previously recorded in the Buller region. It is important that the complexities and community diversity of Mount Rochfort forest be preserved.

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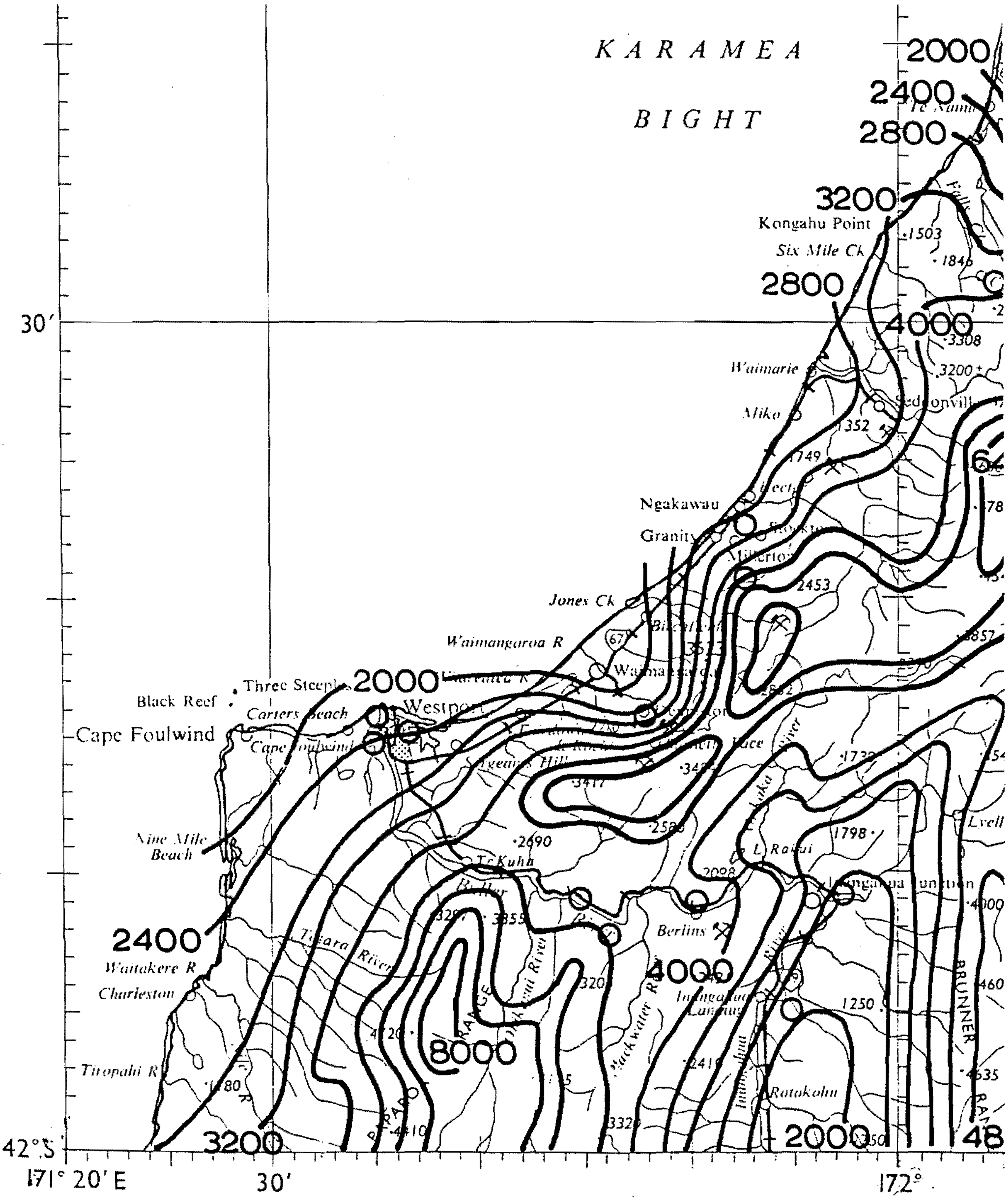
APPENDICES

Appendix 1



Section of map (New Zealand Meteorological Service 1978) showing isohyet distribution in the study area region.

Appendix 2

TWINSPAN two way table of 138 species by 92 plots. Species names are abbreviated to the first three letters of the generic and scientific name. For full names see Appendix 3.

Appendix 3

Full names of all the species recorded in this study.

Aporostylis bifolia (Hook. f.) Rupp et Hatch
Abrotanella linearis Bergg.
Ascarina lucida Hook. f.
Archeria traversii Hook. f.
Asplenium bulbiferum Forst. f.
Asplenium flaccidum Forst.f.
Astelia fragrans Col.
Astelia linearis Hook. f.
Astelia nervosa Hook. f.
Astelia solandri A. Cunn.
Astelia trinervia Kirk
Blechnum chambersii Tindale
Blechnum discolor (Forst. f.) Keys
Blechnum fluviatile (R. Br.) Salom.
Blechnum sp. ("black spot")
Blechnum minus (R. Br.) Ettingsh.
Blechnum procerum (Forst. f.) Swartz
Brachyglottis buchananii (J.B. Armst.) B. Nordenstam
Carpha alpina R. Br.
Carpodetus serratus J. R. et G. Forst.
Celmisia monroi Hook. f.
Coprosma cheesemannii W. R. B. Oliver
Coprosma colensoi Hook. f.
Coprosma crenulata W. R. B. Oliver
Coprosma parviflora var.dumosa Cheesem.
Coprosma foetidissima J. R. et G. Forst.
Coprosma grandifolia Hook. f.
Coprosma pseudocuneata W. R. B. Oliver
Coprosma rhamnoides A. Cunn.
Coprosma robusta Raoul
Corybas oblongus (Hook. f.) Reichb. f.
Ctenopteris heterophylla (Labill.) Tindale
Cyathea colensoi (Hook. f.) Domin
Cyathea smithii Hook. f.
Cyathea medullaris (Forst. f.) Swartz
Cyathodes juniperina (J. R. et G. Forst.) Druce
Dacrydium cupresssinum Lamb.
Dendrobium cunninghamii Lindl.
Dianella nigra Col.
Dicksonia squarrosa (Forst. f.) Swartz
Dracophyllum longifolium (J. R. et G. Forst.)
Dracophyllum traversii Hook. f.
Drosera spathulata Labill.
Earina autumnalis (Forst. f.) Hook. f.

Earina mucronata Lindl.
Elaeocarpus hookerianus Raoul
Empodisma minus (Hook. f.) L. Johnson et D. Cutler
Freycinetia baueriana subsp. banksii (Cunn.) Stone
Gahnia procera J. R. et G. Forst.
Gahnia rigida Kirk
Gahnia xanthocarpa (Hook. f.) Hook. f.
Gaultheria antipoda Forst. f.
Gentiana spenceri Kirk
Gleichenia dicarpa R. Br.
Grammitis billardieri Willd.
Griselinia littoralis Raoul
Griselinia lucida Forst. f.
Halocarpus biformis (Hook.) Quinn
Hedycarya arborea J. R. et G. Forst.
Hypolepis rufobarbata (Col.) N. A. Wakefield
Hymenophyllum armstrongii (Baker) Kirk
Hymenophyllum bivalve (Forst. f.) Swartz
Hymenophyllum demissum (Forst. f.) Swartz
Hymenophyllum ferrugineum Colla
Hymenophyllum flabellatum Labill.
Hymenophyllum lyallii Hook. f.
Hymenophyllum multifidum (Forst. f.) Swartz
Hymenophyllum revolutum Col.
Hymenophyllum rufescens Kirk
Hymenophyllum sanguinolentum (Forst. f.) Swartz
Isolepis aucklandica Hook. f.
Lagarostrobos colensoi (Hook, f,) Quinn
Lastreopsis hispida (Swartz) Tindale
Lepidothamnus intermedius (Kirk) Quinn
Leptopteris hymemophylloides (A. Rich.) C. Presl
Leptospermum scoparium J. R. et G. Forst.
Leucopogon fasciculatus A. Rich
Libertia pulchella (R. Br.) Spreng
Libocedrus bidwillii Hook. f.
Lindsaea trichomanoides Dryand.
Luzuriaga parviflora (Hook.f.) Kunth
Lycopodium billardieri Spring
Lycopodium ramulosum Kirk
Lycopodium scariosum Forst. f.
Lycopodium varium R. Br.
Melicytus ramiflorus J. R. et G. Forst.
Metrosideros diffusa A. Cunn.
Metrosideros fulgens Sol. ex Gaertn.
Metrosideros parkinsonii Buchan.
Metrosideros perforata (J. R. et G. Forst.) A. Rich.
Metrosideros umbellata Cav.
Microlaena avenacea Hook.f.

Myrsine divaricata A. Cunn.
Myrsine salicina Hew. ex Hook. f.
Neomyrtus pedunculatus (Hook. f.) Allan
Nertera depressa Banks et Sol. ex Gaertn.
Nertera dichondrifolia (A. Cunn.) Hook. f.
Nothofagus fusca (Hook. f.) Oerst.
Nothofagus menziesii (Hook. f.) Oerst.
Nothofagus solandri var. cliffortoides (Hook. f.) Poole
Nothofagus truncata (Col.) Ckn.
Olearia colensoi Hook. f
Parsonsia sp. R. Br.
Phormium cookianum Le Jolis
Phyllocladus alpinus Hook. f.
Phymatosorus diversifolius (Willd.) Pichi Serm.
Pittosporum crassicaule Laing et Gourlay
Podocarpus hallii Kirk
Prumnopitys ferruginea (D. Don) Laubenf.
Pseudopanax anomalus (Hook.) Philipson
Pseudopanax crassifolius (Sol. ex A. Cunn.) C. Koch
Pseudopanax colensoi (Hook. f.) Philipson
Pseudopanax linearis (Hook. f.) C. Koch
Pseudopanax simplex (Forst. f.) Philipson
Pseudowintera colorata (Raoul) Dandy
Pseudowintera traversii (Buchan.) Dandy
Pterostylis banksii A. Cunn.
Pterostylis irsoniana Hatch
Quintinia acutifolia Kirk
Ripogonum scandens J. R. et G. Forst.
Rubus cissoides A. Cunn
Schefflera digitata J. R. et G. Forst.
Sticherus cunninghamii (Heward ex Hook.) Ching
Thelymitra venosa R. Br.
Tmesipteris elongata P. A. Dangeard
Tmesipteris tannensis (Sprengl) Bernh.
Trichomanes reniforme Forst. f.
Trichomanes strictum Menzies ex Hook. et Grev.
Trichomanes venosum R. Br.
Uncinia angustifolia Hamlin
Uncinia filiformis Boott
Uncinia gracilenta Hamlin
Uncinia nervosa Boott
Uncinia rupestris Raoul
Uncinia uncinata (Linn. f.) Kuk.
Uncinia zotovii Hamlin
Weinmannia racemosa Linn. f.

Appendix 4

Full list of pH scores and percentages of organic matter and organic carbon for each plot site.

Mount Rochfort

Forest group	Plot number	pH (H20) rep 1	rep 2	Organic matter	Organic carbon
5	B1	-	-	-	-
6	B2	3.30	3.32	14.366	8.332
5	B3	3.47	3.47	31.427	18.228
5	C1	3.67	3.66	9.08	5.266
5	C2	3.56	3.57	10.871	6.305
5	C3	3.08	3.08	14.282	8.284
6	C4	3.63	3.60	6.377	3.697
5	D1	3.80	3.76	6.337	3.675
5	D2	3.03	3.05	40.403	23.434
6	D3	3.75	3.76	46.284	26.844
5	D4	3.48	3.50	9.434	5.472
5	D5	3.45	3.49	14.561	8.445
6	E1	3.89	3.86	6.198	3.594
5	E2	3.45	3.46	23.550	13.659
6	E3	3.71	3.66	6.748	3.914
6	E4	3.02	3.03	94.832	55.003
6	E5	3.49	3.52	21.360	12.389
4	F1	3.73	3.70	9.991	5.794
6	F2	4.04	4.08	44.162	25.614
6	F3	3.27	3.24	92.608	53.712
6	F4	4.13	4.09	26.909	15.607
6	F5	3.85	3.83	15.385	8.923
5	F6	3.42	3.40	19.633	11.387
3	G1	3.09	3.10	8.214	4.764
6	G2	3.61	3.58	6.700	3.886
6	G3	3.08	3.12	23.034	13.360
6	G4	3.43	3.43	18.886	10.953
4	G5	4.17	4.15	9.666	5.610
3	G6	3.80	3.78	4.917	2.851
3	H2	3.67	3.65	9.335	5.414
3	H3	3.53	3.53	10.994	6.376
6	H4	-	-	-	-
4	H5	3.41	3.42	12.067	6.999
4	H6	3.48	3.48	7.959	4.616
3	I1	3.19	3.20	10.075	5.844
3	I2	3.32	3.32	21.089	12.232
1	I3	3.78	3.80	7.918	4.592
3	I4	3.15	3.18	21.69	12.580
3	I5	3.68	3.65	4.569	3.650
6	J1	4.08	4.08	25.039	14.522
4	J2	3.65	3.64	28.384	16.463
1	J3	3.75	3.70	3.525	2.045
3	J4	3.51	3.51	14.910	8.648
3	J5	3.43	3.39	11.102	6.439
3	J6	3.10	3.10	46.180	26.784
4	K1	3.44	3.42	29.101	16.879
3	K2	3.27	3.28	84.885	49.233

Forest group	Plot number	pH (H20) rep 1	rep 2	Organic matter	Organic carbon
3	K3	3.54	3.55	22.770	13.207
3	K4	3.33	3.30	40.047	23.227
4	K5	4.26	4.28	9.949	5.770
3	K6	3.43	3.42	15.314	8.882
2	L1	3.32	3.31	18.604	10.790
2	L2	4.05	4.05	10.785	6.255
3	L3	3.57	3.57	7.073	4.102
1	L4	3.66	3.65	3.358	1.948
3	L5	3.63	3.65	8.890	5.156
3	L6	3.10	3.10	44.673	25.910
2	M1	3.12	3.13	43.562	25.266
2	M2	4.06	3.96	3.868	2.243
2	M3	3.21	3.20	23.460	13.607
1	M4	3.68	3.69	12.708	7.371
2	M5	4.02	4.02	18.949	10.990
2	M6	3.41	3.42	14.410	8.358
2	N1	3.25	3.23	54.734	31.746
2	N2	3.61	3.60	11.624	6.741
2	N3	3.28	3.25	36.528	21.186
2	N4	3.59	3.54	12.334	7.154
2	N5	3.13	3.13	83.921	48.674
2	N6	3.28	3.27	25.248	14.644
1	O1	3.38	3.40	8.412	4.879
1	O2	3.51	3.50	26.933	15.621
2	O3	3.60	3.58	12.921	7.494
2	O4	3.49	3.47	12.248	7.104
1	O5	3.59	3.55	6.059	3.514
2	O6	3.43	3.39	8.204	4.758
Mount Frederick					
6	P1	3.62	3.66	16.006	9.283
6	P2	3.30	3.30	28.049	16.268
3	P3	3.49	3.45	16.763	9.723
2	P4	3.23	3.24	25.915	15.031
1	P5	3.28	3.28	47.233	27.395
2	P6	3.23	3.25	97.152	56.348
2	P7	3.38	3.38	8.306	4.817
2	P8	3.21	3.19	78.213	45.364
2	P9	3.16	3.17	94.637	54.889
6	Q1	3.16	3.17	20.650	11.977
6	Q2	3.68	3.69	28.827	16.720
6	Q3	3.79	3.80	16.896	9.780
4	Q4	2.98	2.98	95.953	55.652
4	Q5	3.23	3.24	35.436	20.553
4	Q6	3.34	3.33	18.980	11.008
2	Q7	3.36	3.32	21.433	12.431
2	Q8	3.57	3.56	10.821	6.276

Appendix 4

Ratings for soil properties used by the Soil Bureau for New Zealand soils (after Palmer *et al* 1986).

Rating	pH (1:2.5 soil:water)	Organic C%
Very high	) >9.0 (extremely alkaline)) 8.4-9.0 (strongly alkaline)) 7.6-8.3 (moderately alkaline)	>20
High	) 7.1-7.5 (slighly acidic)) 6.6-7.0 (near neutral)	10-20
Medium	) 6.0-6.5 (slightly acidic)) 5.3-5.9 (moderately acidic)	4-10
Low	4.5-5.2 (strongly acidic)	2-4
Very low	<4.5 (extremely acidic)	<2